

UTILITY SCALE

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Key points from Group 1 discussion

- Many benefits associated with components that can operate at higher frequencies at higher voltages
 - Benefits: lower weights (but debatable benefit)
 - Higher bandwidth = better grid facing functionality (harmonics, ride through...)
 - Better efficiency
 - Reduced passive component requirements = capacitor reliability

Key points from Group 1 discussion

- What should be the focus?– lower system costs versus increased functionality/reliability
 - Past a certain point ($\sim \$0.10/\text{W}$) lower cost less important than system reliability and functionality
 - Reliability approaches
 - Communication/sensing
 - Technologies that streamline commissioning
 - Better encapsulation/thermal management approaches

Key points from Group 1 discussion

- Modular level power conversion and peak power tracking
 - Need better system impact understanding and metrics to decide what functionalities should be put upstream versus downstream
- Test and certification for grid operating requirements
 - Reliability is impact on lost revenue
- Automated commissioning and grid monitoring and control
 - Better sensors and instrumentation to detect faults and degradation
 - Automated data analysis to produce actionable information = predictive system performance and health
 - Reliable utility communication

1. For grid connected systems, what electrical components are necessary between the module and the grid? What is the state-of-the-art performance for each of these components?
 - 10kV+ transistors
 - 10kV+ Diodes
 - Capacitors
 - High-frequency PE transformers with high isolation
 - Packaging of semiconductor
 - Copper cost is extremely high. If you can go to higher V, you might be able to use cheaper materials
 - Nanocrystalline magnetics
 - SiC or GaN switches
 - Inductors

Components between module and grid - State-of-the-art performance

- Conventional DC bus to grid tied
 - Med v Schotky diodes
 - **Frequency higher** – grid benefits EMI down and rid harmonics down, passive component – less passive materials and more reliable (**get rid of capacitors**)
 - Hit Cost targets
 - Still meet 519
- On module
 - Capacitance – don't want to eliminate
 - More V on DC bus, the more VAR regulation
 - Probably will increase module cost
 - Large scale inversion – electronics represent many other things
 - Safety – fusing, fault detecting
 - Performance monitoring
 - Grid response
 - Relook partitioning of all functions to figure out lower cost
- Saving weight might not get you anything
 - Without transformer, “it” ends inside the inverters – meaning utilities own all the way up to that point. Scary thought (and utilities don't want that anyway)
 - Transformer has some usefulness – so utilities don't want to get rid of it.
 - Harmonics

Architectures

- Conventional DC bus to grid-tied inverter
- AC modules direct to grid
- DC/DC converters on modules with grid-tied inverter
- 480V three phase system with medium V transformer to 12kV.
 - 60Hz transformers (high weight and size component - transportability)
- Inverter w/ no transformer 208 V output and outside transformer steps up 208 to 12kV

Architectures

2. What are the critical attributes for a utility-scale (ground) mounted converter? EXPLAIN. How do the above architectures compare for each of these attributes?

- Efficiency
 - Weighted average number – not peak number
 - 97, 97.5% weighted (entire inverter)
 - What do we gain by going up
 - Cooling losses less
 - Reliability benefits
 - Approaches to get:
 - Soft switching converters
 - Staged/modular inverter that kick in and out so as to optimize efficiency at each range
- Operating temperature range
 - Driven by module temp/irradiance
 - Thermal cycling, power cycling
- Power quality
- Plant monitoring

Achievable power density and cost targets (1 MW @ 500 lbs)

3. Today's MW inverters have a power density of 1MW/10,000lbs at \$0.17/W-\$0.22/W? What are desirable (achievable) targets for this power density?

- Driving down the cost below where the vehicle is not as important, it's the functionality of the inverter at that cost
 - Cost /kWh is the important metric
 - Integrate at high penetration levels
 - Performance on the grid
- Smaller scale not apples to apples
 - Harmonics not important at smaller scale
 - No Filters which weigh ton
 - Not 100 different vendors who could potentially wire in
- Approach: Soft-switching – SiC Schotky
- Modular 55kW and stack them all together, but still need transformer somewhere

Light weight converters – risks and benefits

4. What are the additional benefits and risks associated with light weight inverters?

Benefits	Risks
Siting easier	Costs
No crane, no road	Utilities like transformers and reconfigurability
Transportation costs – all in one truck?	Safety regulations
Leverage commercial markets	Potential efficiency loss
Modularity - less equipment so place separately	Standardized systems take out optimization at each site
Place inverter on roof	
Pre-fab	
Streamling testing	
Standardized systems – cost benefits	

Module-scale MPPT for utility installation – risks and benefits

5. What are the benefits and risks for module-scale MPPT for utility installation?

- Cell level doesn't make sense
- Cell-string level and replace diodes (smart power diode)
- Module to module and string level for converters

Benefits	Risks
Reducing wiring costs	Reliability
Save land and structure	Advanced system monitoring – need to know which panel fails
Pack modules denser	
Maximize output	
On peak production	

Inverter reliability and failure modes

6. What are the standard measures of inverter reliability? What are the dominant failure modes for utility-scale inverters?
- Downtime (Not lifetime) – time not producing power
 - \$ lost on production
 - Availability
 - Failure mode
 - Inability to respond appropriately to abnormal grid condition
 - Component – cycling reliability
 - Capacitors
 - Cooling – environmental impacts
 - Enclosure
 - Inverters not tested properly – need qualification test
 - Techs to improve
 - More sophisticated cooling mechanism
 - Better packaging

Diagnostic capabilities required of the inverter

7. What are the critical diagnostic capabilities required of the inverter?

- Fault detection, management, and tolerance
 - Isolate parts of system and design workarounds for various faults.
 - Inverter send standard protocol to utility
 - Availability for next day
 - How much of your potential you are losing – for optimal maintenance timing
 - Measuring weather – should know if your putting out what you should be putting out
- Module monitoring
 - Finding installation errors on the onset
 - Automated commissioning process